DSO ENTITY
DSOs FOR EUROPE

Grid Forming Capabilities DSO Update
ESC GC 27 June 2024

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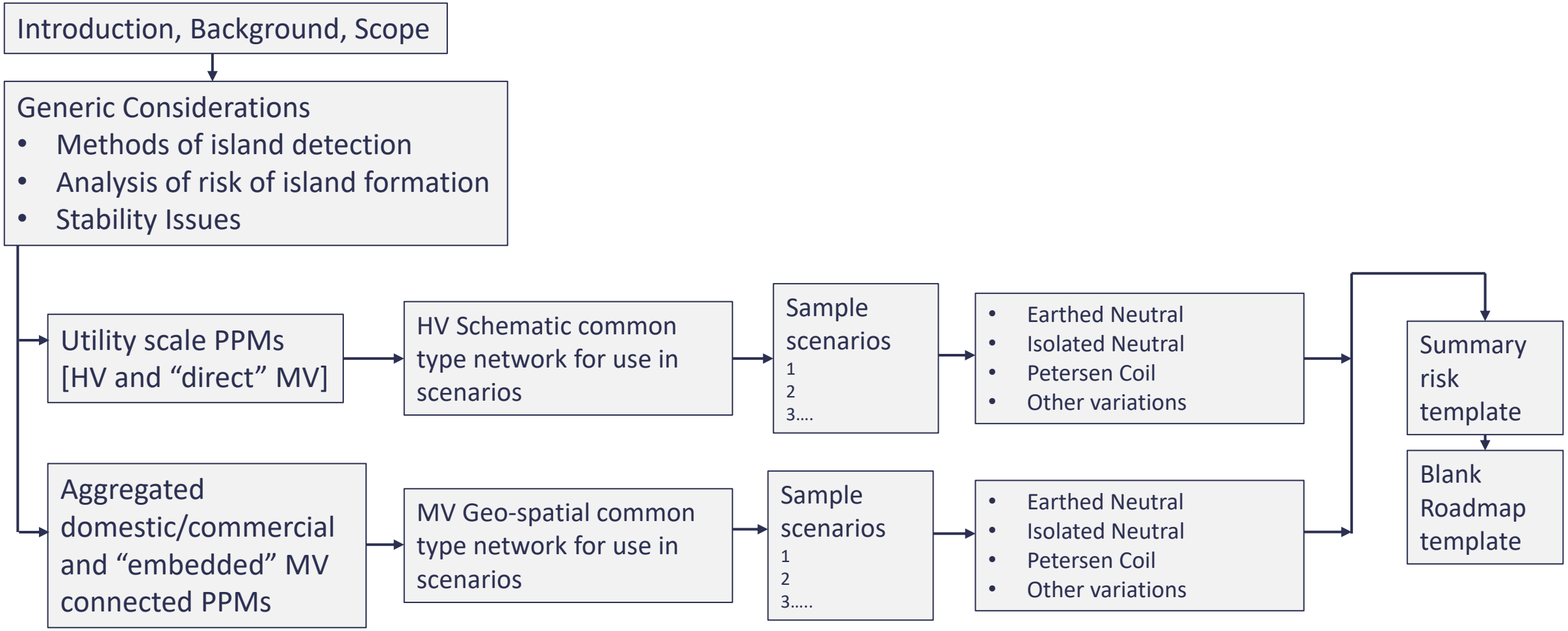
Evolution of Guidance Document for DSOs on creating Roadmaps

- Survey of representative DSOs mentioned at last meeting
- Some outcomes can now be shared
- Work continues on this document
- Risk-Mitigation Matrix under construction
- Structure of the document emerging

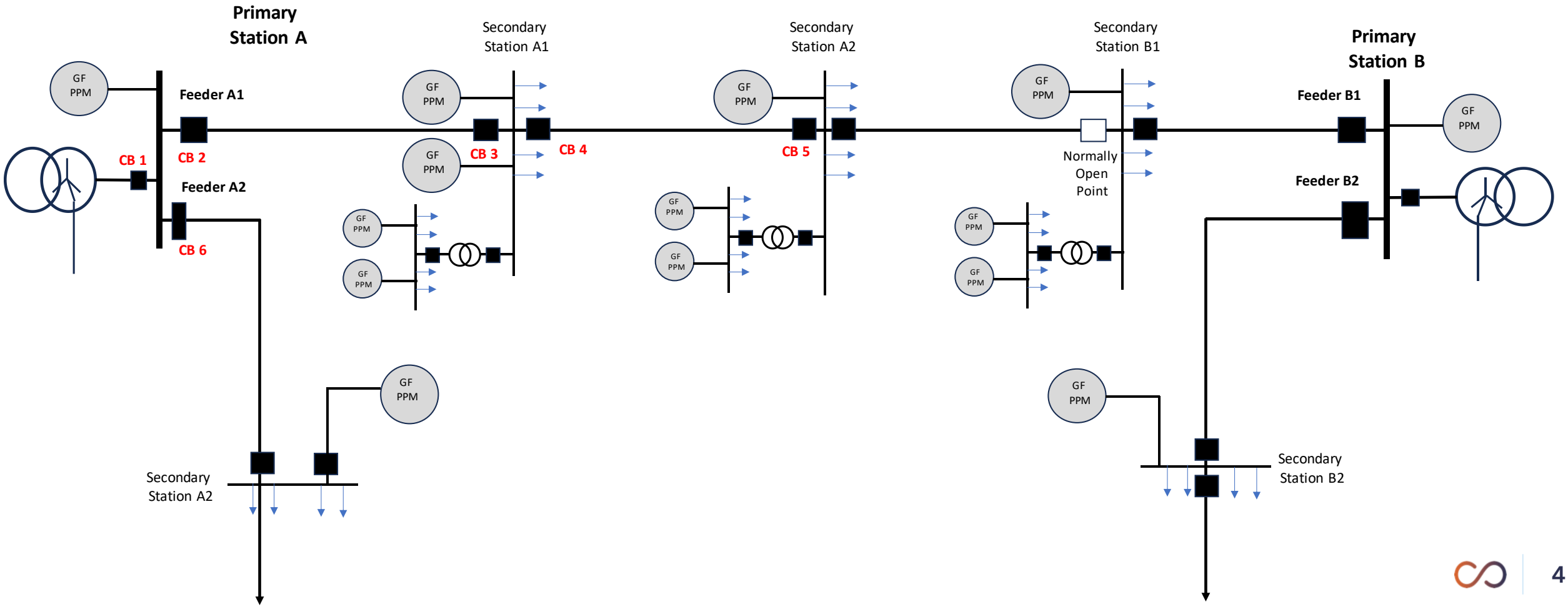
“Guidance on the creation of a roadmap to the introduction of high penetrations of Grid Forming Power Park Modules [PPMs] onto distribution systems”

Emerging Document Structure [WIP]



HV Schematic common type network for scenario consideration

The network below is used throughout the document when considering risks and mitigations for islanding scenarios for “HV” type networks and “direct” MV PPM connections.



Risk-Mitigation Matrix

- Each neutral treatment being considered separately
- Topology ie “Direct” and “Embedded” being considered separately
- For each,
  - Risk
  - Mitigation
  - Post mitigation risk,

explored.

Acronyms		
	ADMS	Advanced Distribution Management System
	NVD	Neutral Voltage Dsplacement
	ODV	Open Delta Voltage

Type/Topology	Neutral treatment	Risk	Impact	Mitigation	Post Mitigation risk	Remarks			
“Direct” per DSO Entity graphic	Isolated	Loss of earth fault protection	Public safety / Fatality	NVD or ODV at all GFC Connection Points	None				
				Islanding detection function in place as part of ADMS	Lower. Assuming that islanding occurrence is flagged in Control Centre, Operator can manually disconnect GFC sources.	Assumes that ADMS and associated visibility is in place and that all such sources are included in the connectivity model.	ADMS coverage much greater at higher voltages		
	Direct earthed - residual or neutral current based earth fault protection at primary substation	Island operates as isolated neutral - no earth fault protection in place	Public safety / Fatality	NVD or ODV at all GFC Connection Points	None				
				Permanent neutral earth at all GFC Connection Points.	Operation of EF protection during normal operation would be compromised	If no grid transformer at Connection Point, then an earthing transformer would also be required			
				Switchable neutral earth at all GFC Connection Points.	none	Would still need NVD or ODV at all GFC Connection Points to detect earth fault and operate neutral earth switch	If no grid transformer at Connection Point, then an earthing transformer would also be required		
				Islanding detection function in place as part of ADMS	Lower. Assuming that islanding occurrence is flagged in Control Centre, Operator can manually disconnect GFC sources.	Assumes that ADMS and associated visibility is in place and that all such sources are included in the connectivity model.			
		Transient overvoltages - plant/Lightning Arrestors not rated for full Line-voltage	Plant damage	Permanent neutral earth at all GFC Connection Points.	Operation of EF protection during normal operation would be compromised	If no grid transformer at Connection Point, then an earthing transformer would also be required			
			Continuity	Permanent neutral earth at all GFC Connection Points.	Operation of EF protection during normal operation would be compromised	If no grid transformer at Connection Point, then an earthing transformer would also be required			
				Switchable neutral earth at all GFC Connection Points.	none	Would still need NVD or ODV at all GFC Connection Points to detect earth fault	If no grid transformer at Connection Point, then an earthing transformer would also be required		
				Islanding detection function in place as part of ADMS	Lower. Assuming that islanding occurrence is flagged in Control Centre, Operator can manually disconnect GFC sources.	Assumes that ADMS and associated visibility is in place and that all such sources are included in the connectivity model.			
	Petersen Coil /Arc Suppressed - 1 No EFT and policy is to feed load during a single phase earth fault.	Loss of earth fault protection	Public safety / Fatality	Permanent ASC at all GFC Connection Points.	Coil can only be a fixed size [EF Amps], therefore can only match for a specific island. Any variation in where the separation occurs will cause under or over suppression so touch/step voltge risk to the public at site of earth fault remains.	Would still need NVD or ODV at all GFC Connection Points to detect earth fault and operate neutral earth switch	If no grid transformer at Connection Point, then an earthing transformer would also be required	Coils could be aized to cater for any shallow connections to the GFC. This would be an advantage in that the main coil at the primary substation would not have to do so.	
		Transient overvoltages - plant/Lightning Arrestors not rated for full Line-voltage	Plant damage Continuity	Permanent ASC at all GFC Connection Points.	none				
				Islanding detection function in place as part of ADMS	Lower. Assuming that islanding occurrence is flagged in Control Centre, Operator can manually disconnect GFC sources.	Assumes that ADMS and associated visibility is in place and that all such sources are included in the connectivity model.			
	Petersen Coil /Arc Suppressed - 2A ASC is used only for transient arc suppression and back up EFT based on NVD or ODV is in place. Sufficient NVD or ODV voltage to ensure tripping.	Loss of earth fault protection for transient faults	Public safety / Fatality	Risk needs to be assessed in the context of exposure during tripping time out. May be deemed to be acceptable.	May be deemed to be acceptable.				
		Transient overvoltages - plant/Lightning Arrestors not rated for full Line-voltage	Plant damage	Risk needs to be assessed in the context of exposure during tripping time out. May be deemed to be acceptable.	May be deemed to be acceptable.				
			Continuity	Risk needs to be assessed in the context of exposure during tripping time out. May be deemed to be acceptable.	May be deemed to be acceptable.				
	Petersen Coil /Arc Suppressed - 2B ASC is used only for transient arc suppression and back up EFT based on NVD or ODV is in place. High resistance fault. Insufficient NVD or ODV voltage to ensure tripping.	Loss of earth fault protection	Public safety / Fatality	Permanent ASC at all GFC Connection Points.	Coil can only be a fixed size [EF Amps], therefore can only match for a specific island. Any variation in where the separation occurs will cause under or over suppression so touch/step voltge risk to the public at site of earth fault remains.	Would still need NVD or ODV at all GFC Connection Points to detect earth fault and operate neutral earth switch	If no grid transformer at Connection Point, then an earthing transformer would also be required	Coils could be aized to cater for any shallow connections to the GFC. This would be an advantage in that the main coil at the primary substation would not have to do so.	
		Transient overvoltages - plant/Lightning Arrestors not rated for full Line-voltage	Plant damage Continuity	Permanent ASC at all GFC Connection Points.	none				
				Islanding detection function in place as part of ADMS	Lower. Assuming that islanding occurrence is flagged in Control Centre, Operator can manually disconnect GFC sources.	Assumes that ADMS and associated visibility is in place and that all such sources are included in the connectivity model.			

Neutral treatments /earthing arrangements

Neutral treatments/earthing arrangements					
Voltage level [kV]	Direct earthed	Isolated	Peterson coil	Resistance	Other?

- Surprising outcome is that there is a spread of neutral treatments across and within this representative sample of DSOs
- These include;
  - Direct earthed
  - Isolated neutral
  - Petersen Coil
  - Resistance earthed
  - Some other variations
- This is relevant to informing the nature of mitigations required.

Neutral treatments/earthing arrangements					
Voltage level [kV]	Direct earthed	Isolated	Peterson coil	Resistance	Other?
All except LV					
All except LV			Yes		
LV	Yes [PME]				
10kV rural		Yes			
10kV urban		Yes [with directional EFT]			
20kV				20 Ohm	
38kV			Yes		
DSO operated 110kV	Effectively earthed/switched neutrals				
LV	Yes	Yes		Yes	Grounding choke - not peterson coil
All other voltages					
132/33/11	Yes			1000A Fault current	
			In some cases Petersen coil is used for earth fault capacitive current compensation. (the range of the current is between 100-300A)	80 ohm 40 ohm in some cases	
	Yes		Some cases	12, 40, 80 Ohm	40 Ω + j 40 Ω (legacy. Not installed any more)
				In some cases is done with resistance. 20-76 Ohms (depending on the voltage level)	Reactance is usually implemented
	HV – yes (earthing is carried out at the EHV/HV transformers but not in the HV level in the HV/MV networks)			There may be a small resistance if short-circuit is nearing its maximum sizing.	MV – A reactance (not a resistance) is used. The fault current is limited to 300A (rural networks) or 1000A (urban networks)
MV - Mainly (more than 90% of total lenght) 15/20 kV HV – Mainly (more than 90% of total lenght of sub-transmission grid) 150/132 kV	All distribution TRs have the primary winding present the neutral point ungrounded. In general the HV network is strictly earthed	15% of HV/MV of substations are ungrounded (isolated)	80% of HV/MV substations are equipped with Petersen Coil (resonant impedance)	About 5% of HV/MV stations with high value of resistance (400-500 Ω)	

Loss of Mains / Anti-islanding protection

Loss of Mains /Anti-islanding protection										
Installed Yes /no?	Any voltage or MW trhesholds?	Under voltage	Over voltage	Under frequency	Over frequency	ROCOF		Vector Shift		Others?
						Yes/No?	Setting	Yes/No?	Setting	

- Some consistency with most having the basic forms of protection eg,
  - Under/over voltage
  - Under/over frequency
- Variation on use of other means such as,
  - ROCOF
  - Vector Shift
- Seen as a proxy for the existing risk appetite of DSOs for islanding.

Loss of Mains /Anti-islanding protection										
Installed Yes /no?	Any voltage or MW trhesholds?	Under voltage	Over voltage	Under frequency	Over frequency	ROCOF		Vector Shift		Others?
						Yes/No?	Setting	Yes/No?	Setting	
Yes ("NA-Schutz")	>= 30 KVA central. < 30kVA integrated allowed	0.8/0.45	1.1/1.25	57.5 Hz	51.5 Hz	Yes	2 Hz/s	No		Active methods like frequency-shift implemented in converters, passive methods like three-phase-measurement in combination with ROCOF are also allowed
Yes	LV less onerous	Yes	Yes	Yes	Yes	Yes	1.0 Hz/s	Yes	12 deg.	No
Yes No		Yes	Yes	Yes	Yes					
Yes	>50	0.8 pu, 2.5s	1.10pu, 1s and 1.13pu 0.5s	47.5Hz, 20s, 47.0Hz, 0.5s	52 Hz, 0.5s	1.0, 0.5s		No Banned		
Yes	No	(Un-15 %, 2s	Un+11 %, 2s	47 Hz	52 Hz	Yes Types B, C and D	2 Hz/s 5s?			
Yes	No	85% Un	115%Un	47,5Hz or 49,5Hz	50.5 or 51.5Hz.	Yes for feeders with fast reclosers	F0 +- 0,5Hz and -0,5Hz/s			
Yes	No	No	110%-115%	No	No	No		Yes	20 deg	
Yes	>0.25MW	Yes	Yes	Yes	Yes	No		No		
Yes		Yes	Yes	Yes	Yes	Italy – YES, just for FRT on controlling of inverter				
Yes		Yes	Yes	Yes	Yes	if specifically requested by SO				
Yes		0,8 Un, <=1,5s	1,1 Un (10-minute average), <=0,1 s and 1,15 Un, <=0,1s	47,5 Hz, <=0,1 s	51,5 Hz, <=0,1 s	No		No		
Yes	No	0,85Un/3,2sec . 0,85Un/3,2sec 0,3Un/1,2sec	1,05Un/603 sec average value (LV) , 1,05Un/603 sec average value (LV)	47,5Hz/0,5 sec	52Hz/0,5sec	Yes		No		
Yes	<50kW for ROCOF	Yes	Yes	Yes	Yes	Yes	2 Hz/s			
Yes	No	Yes	Yes	Yes	Yes	No		No		No
Yes	No	0.3 Uc 0.2-0.5s 0.8 Uc 0.2s-1.5s	1.05 -1.15Uc <=0.1s 1.02-1.05Uc <=60s	47.5 Hz, <=0.1s	51.5 Hz <=0.1s	No		No		No

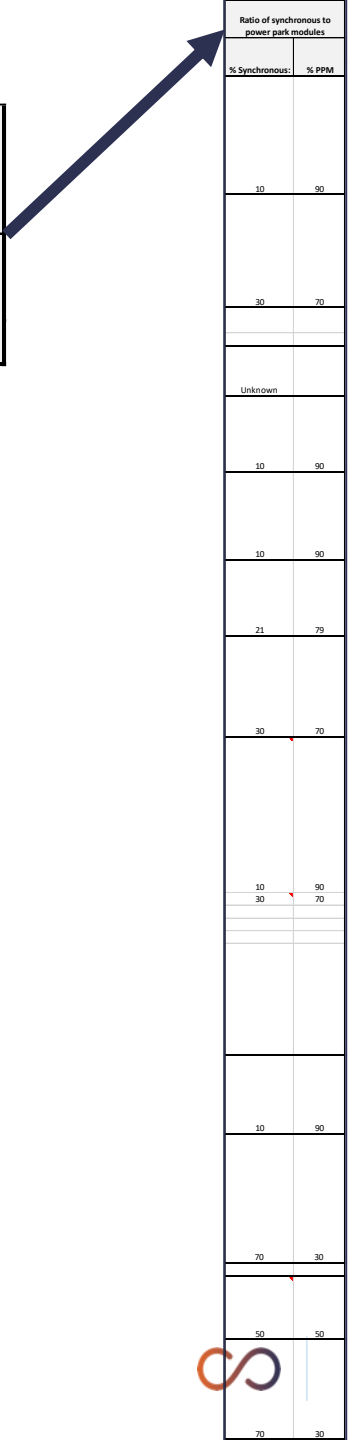
Instances of running islands deliberately?

- Vast majority of respondents indicated “No”
- A small number of cases being considered for a variety of use-cases such as,
  - Blackstart
  - Local planned/unplanned outages
  - Storage systems
  - Major storms.

Ratio of synchronous to power park modules

- Quite a spread here ranging from,
- 10% Synchronous, 90 % PPM to
- 70% Synchronous, 30 % PPM

Ratio of synchronous to power park modules	
% Synchronous:	% PPM



Ratio of Grid Following to Grid Forming

Ratio of Grid Following to Grid Forming			
Now		by 2030	
% Forming	% Following	% Forming	% Following

- For “Now”, quite consistent outcome of around
  - 0-10% Forming
  - 90-100% Following.
- For “by 2030”, responses ranges from,
  - 10% Forming, 90% Following to
  - 50% Forming, 50% Following